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# A climatology of Clouds and Precipitation in Extratropical Cyclones based on satellite observations

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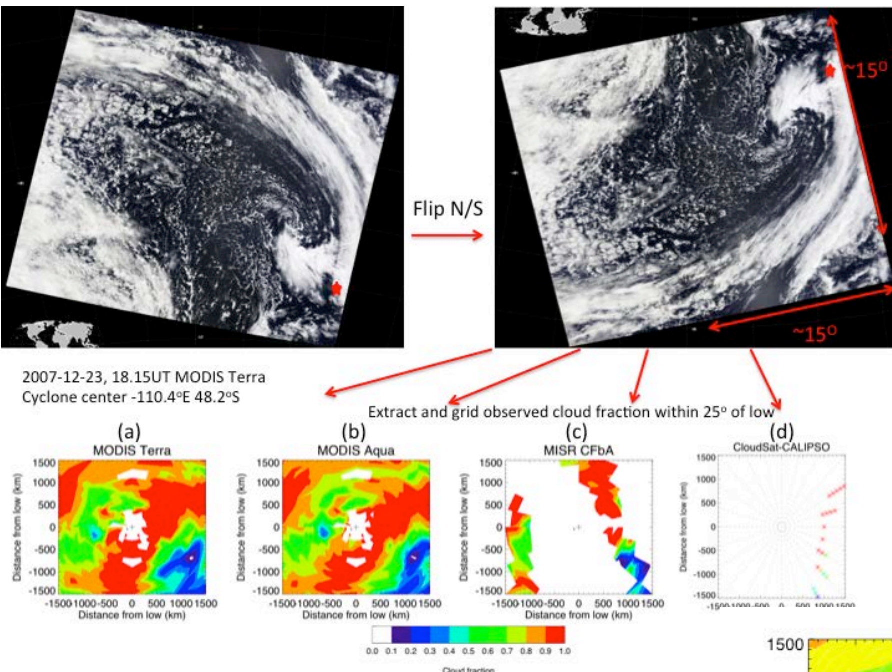
# Why do we focus on extratropical cyclones?

- Extratropical cyclones (ETCs) = major purveyor of precipitation in the midlatitudes, associated with strong winds and other extreme events, and yet no consensus on their evolution in a warming climate (e.g. Lambert and Fyfe, 2006; Bengtsson et al 2009; Feser et al. 2015), in part because of issues in model representation of moist processes.
- Compositing technique and satellite observations offer a new direction for developing metrics to evaluate general circulation models (GCMs)
  following work of Lau & Crane (1995), Bauer and Del Genio (2006), Field and Wood (2007), Bodas-Salcedo et al 2012, 2014, 2016, Polly and Rossow (2016) etc...

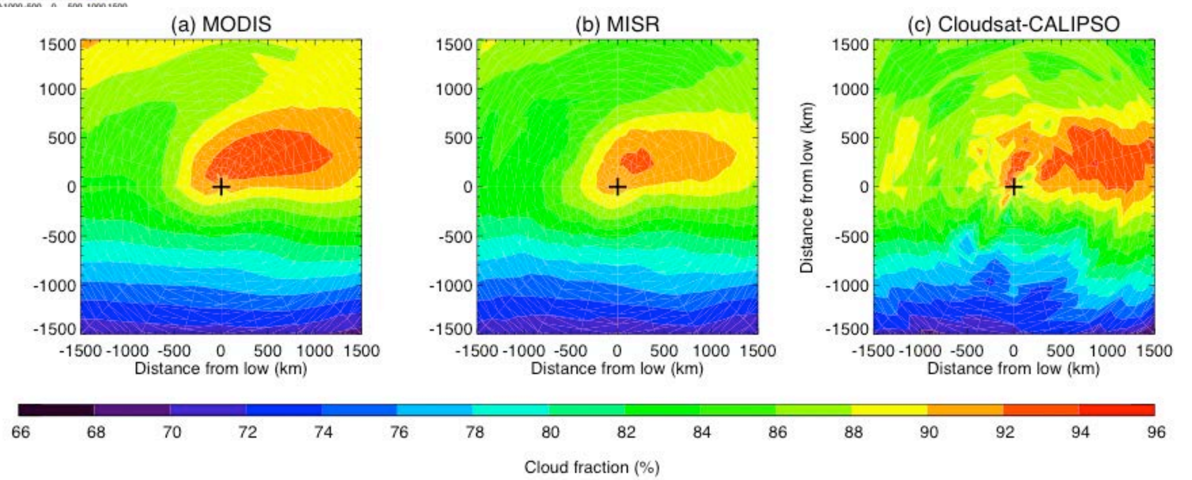
# Model evaluation of total cloud cover

- Use MCMS database (Bauer and Del Genio, 2006; Bauer et al. 2016) to locate ETCs (6-hourly, based on minimum SLP from ERA-interim)
- Composite MODIS *Aqua* daily cloud cover (4-year average) + MISR, CloudSat-CALIPSO etc
- Same method to extract and composite model cloud cover

# Cyclone centered compositing of satellite observations: uncertainty analysis




- Select a collection of cyclone instances
- Keep those with observations within 2500 km and ±3 hours
- Project observations onto same cyclone centered grid then average
- For SH vs NH comparison: flip SH cyclones along N/S
- Below: **SH summer composites of cloud cover: OBSERVATIONS**

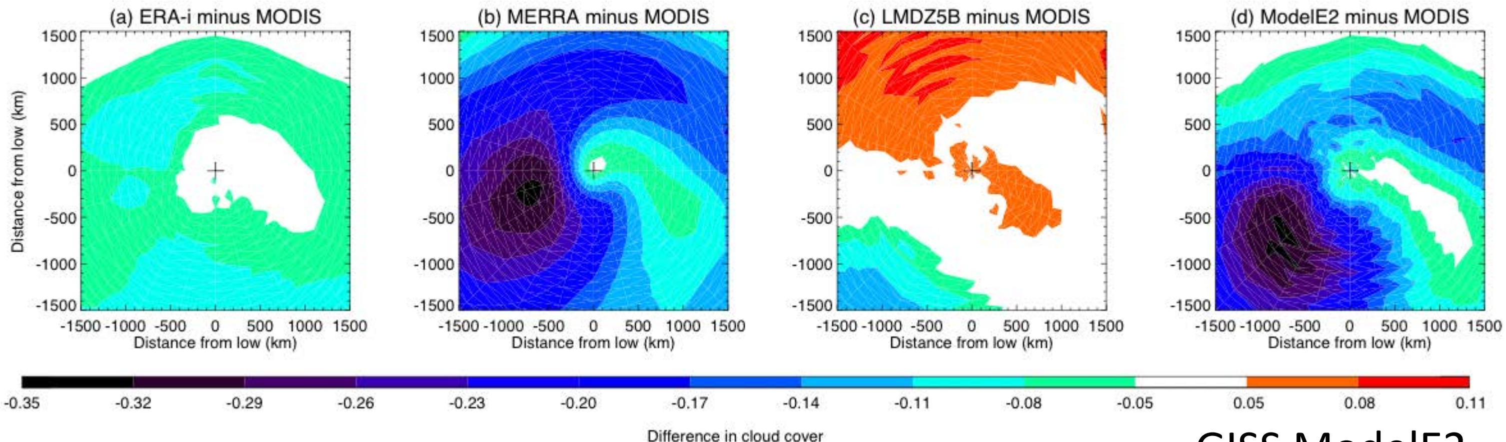



Comparison between MODIS, MISR, and CloudSat-CALIPSO: differences at most **5%**
*Naud et al., JGR 2013*

# Reanalysis and GCMs: SH summer cloud cover in ETCs vs. MODIS

reanalyses

AR5




ERA-interim
Max bias ~10%

MERRA:
bias > 30%

LMDZ-5B (3.75°x3.75°): bias < 14%

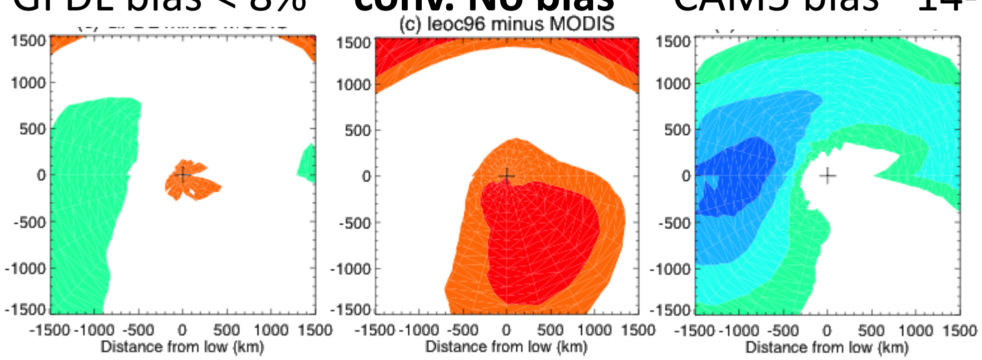
GISS ModelE2 (2°x2.5°): bias >30%

**AR5 -> AR6**

GFDL bias < 8%

**GFDL-Donner conv. No bias**

CAM5 bias ~14-17%

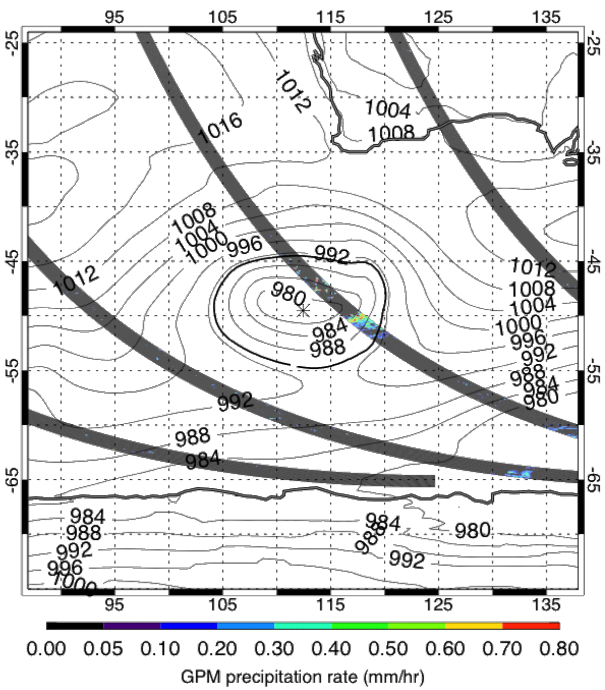



CAM5: 0.9375°x1.25°
GFDL: 1°x1.25°

=> Negative bias in post-cold frontal region, all models underestimate low-level supercooled cloud (c.f. Bodas-Salcedo et al 2014, 2016 for SW bias)
=> Differences between models not caused by differences in large-scale cyclone properties <u>nor resolution</u>

# Can we do the same for precipitation?

**GPM** combined Ku radar+GMI product: 245 km wide swath, 5 km resolution, March 2014 onward

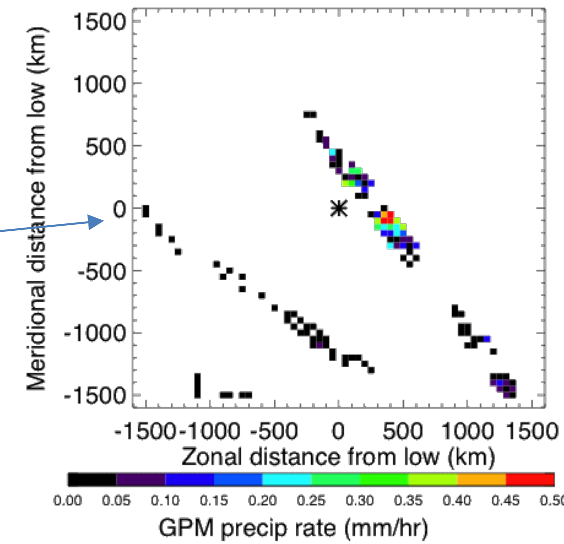



Southern Ocean cyclone: 2015-01-01, 06 UT
Latitude= 49.53°S Longitude=112.43°E
Contours= MERRA-2 SLP
Dark bands: 4 GPM orbits
Colored pixels: Ka+Ku+GMI precipitation rate
Orbits start time: 03:02UT, 04:34UT, 06:07UT and 07:39UT
Note -65°S limit for orbits

Use 50 km resolution <u>equal area</u> cyclone centered grid =>

Potential problems:

- Nb of sampled cyclones
- Time period
- Area of cyclone sampled
- Sensitivity threshold to light/high precipitation rates

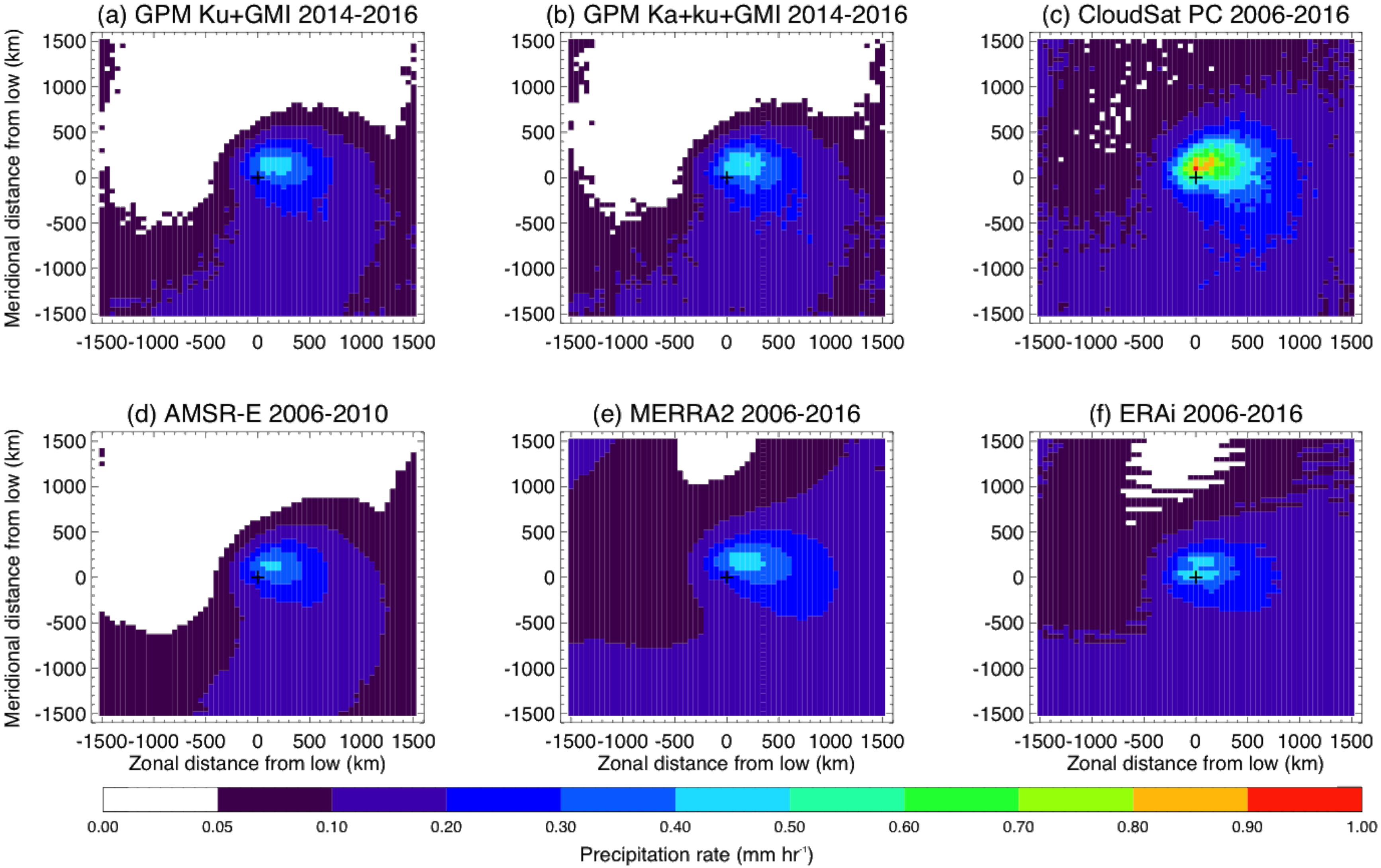



Projected in 50 km x 50 km pixel grid centered on low

For uncertainty estimate, do the same with:

- CloudSat PRECIP-COLUMN 2006-2016
- AMSR-E 2006-2010
- MERRA2 2006-2016
- ERA-interim 2006-2016

# Cyclone centered composites: intercomparison

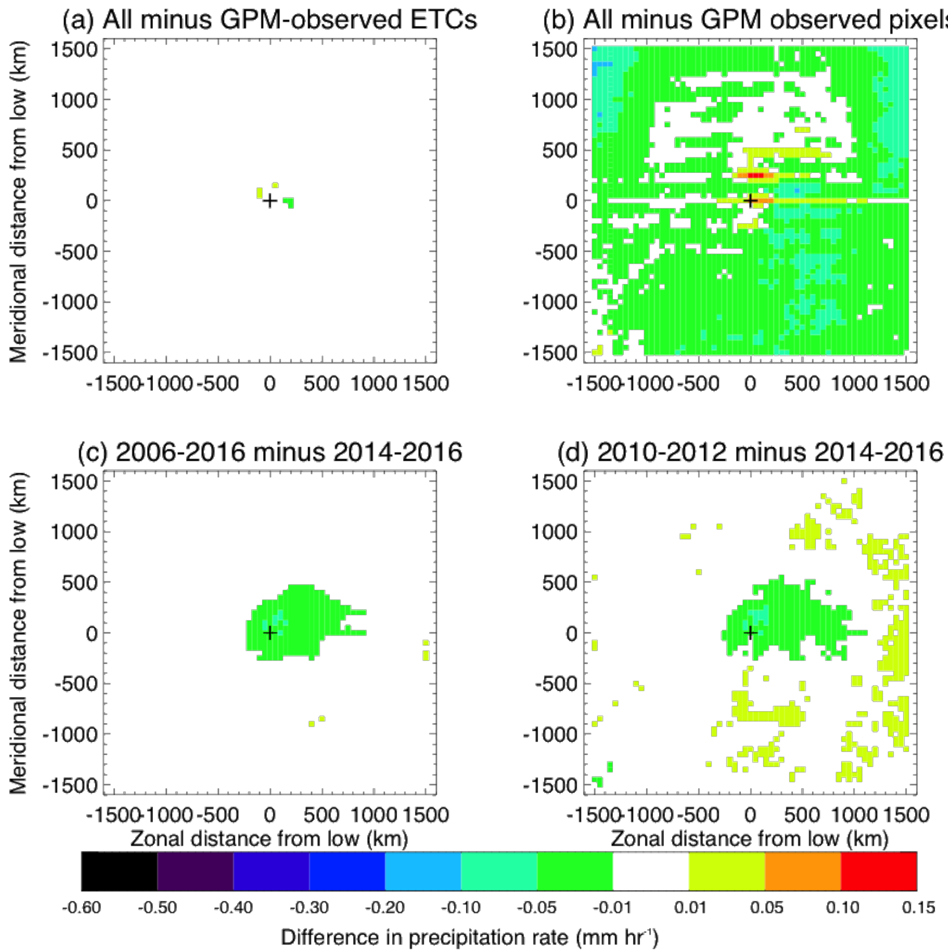


# Impact of sampling: use MERRA2

GPM observes only some of the cyclone area, MERRA2 simulates the entire area: use **MERRA2 precipitation** to evaluate impact of non-uniform observations sampling

All cyclones minus cyclones partly sampled by GPM: no difference

For cyclones observed by GPM: all area minus only grid cells ”seen” by GPM => significant differences esp. at center

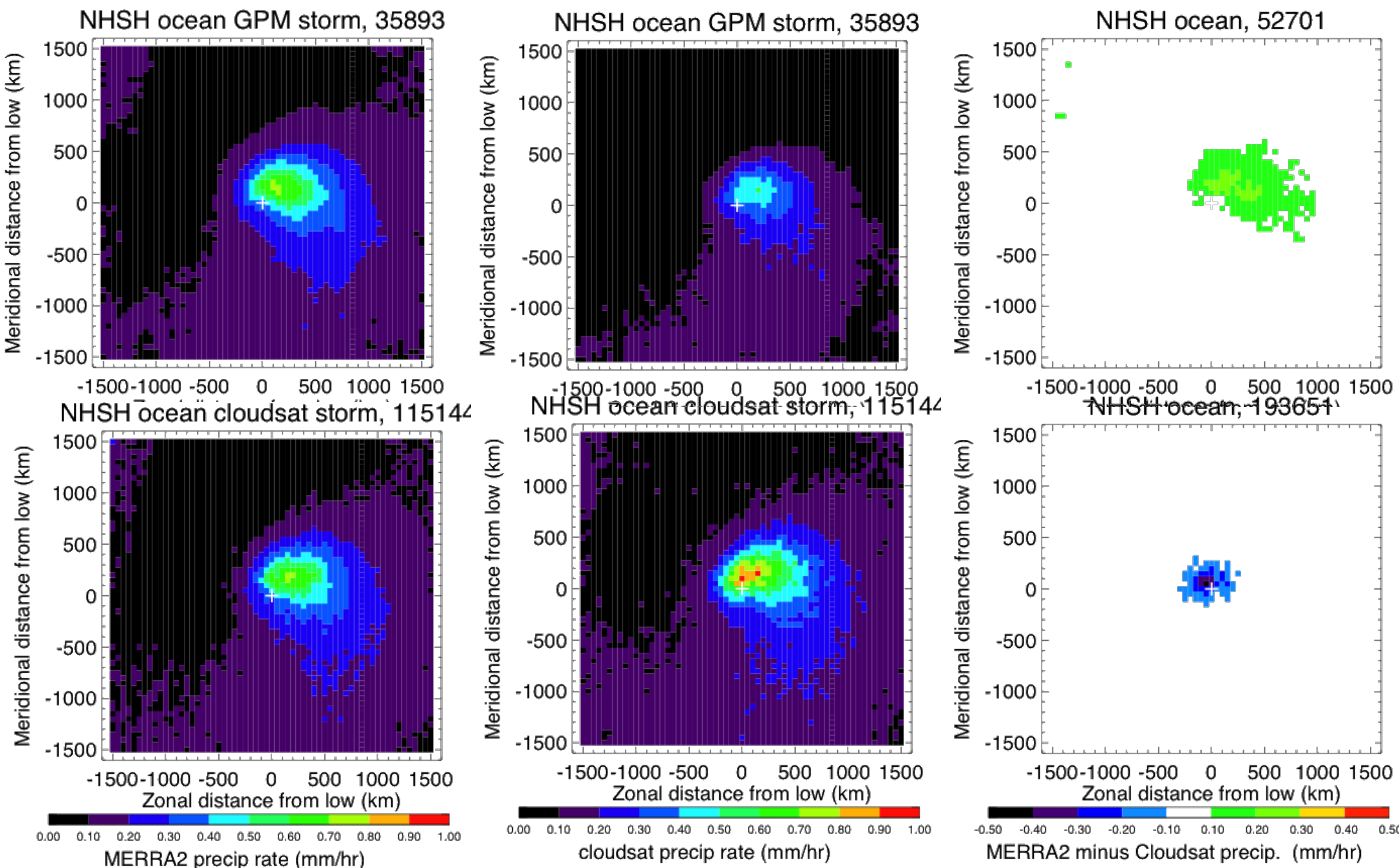



Limited period with GPM, 2014-2016 vs 2006-2016: Difference near center

2010-2012 vs 2014=-2016: same as when comparing to 2006-2016, so not period length but interannual variability

# Comparing MERRA-2 to GPM and Cloudsat

Sample MERRA2 along GPM/CloudSat orbits; GPM Ka+Ku+GMI 2014-2016; CloudSat Precip-Column 2006-2016




Largest differences at center:

- MERRA2 > GPM
- MERRA2 < CloudSat

=> Need to characterize both instruments sensitivity

Good news: We have a range for reference

# Summary

- Cyclone compositing + A-train: helps obtain robust statistics for cloud properties, and much more can be done to understand moist processes in ETCs with this unique dataset => useful evaluation tool
- Also very useful to evaluate other datasets, and apply to more complex data such as precipitation
- Next tasks:
  1) creation of a database of observations in cyclones GPM-ETC and CloudSat-ETC soon to be available on GISS website = orbits segments extracted and saved with ETC information (location, fronts)
  to be enriched with cloud centric datasets
  2) explore frequency of occurrence of precipitation in models and observations